TWIN LAW OF "BÖRZSÖNY" WITH MEASURABLE TWINNING — AND COMPOSITION — PLANE FROM HUNGARIAN ANDESITE

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SUMMARY

Normal twin-laws according to (110) and (130) respectively according to the left forms of these could be established for the first time for plagioclase twin-crystal groups figuring as andesite porphyric phenocrysts (1974). Although these twin-laws could be established from the measured optical data by means of vectorgeometrical computations, no composition — respectively twinning — planes could be determined with them. The plagioclase twin crystal dealt with in what follows occurred in one of the andesite samples collected in the Visegrád mountains. With this twin complex the composition — and twinning — plane of the Börzsöny-twin-law, $(1\bar{1}0)$, between two twinned parts being in immediate contact could well be detected and measured. Values obtained with the measures are in good agreement with those obtained from computations, proving that normal twin laws according to (110) and (130), respectively according to their left forms can be present with plagioclases found in nature.

The andesite sample comes from the Dömörkapu quarry (Visegrád mountains). The rock is a medium- or dark -grey, fresh pyroxene andesite. Microscopically it contains microcavities the internal walls of which are lined at places by green nontronite. The texture of the pyroxene andesite is microhemicrystallic-porphyric. Its mineral components are: *plagioclase, ortho-and clino-pyroxene and opaque mineral.* The amount and crystallization degree of the matrix proves that it is an effusion rock and not a subvolcanic one. The porphyric components are: plagioclase, pyroxene; their dimension is: 150 – 1700 μ. Between plagioclase and pyroxene many oriented intergrowths can be seen, and they appear sometimes as inclusions within each other.

The rock is containing so called "cognate inclusions" also, i.e. inclusions from the depth (gabbro, diabase).

On the evidence of the texture crystallization might have occurred in two magma chambers, but the solidification of the rock took place on the surface. Owing to the idiomorphic development of the porphyric phenocrysts it is probable that the formation had been stagnant in a magma-chamber of high temperature and the outflow took place afterwards.

In the crystallization process of plagioclases two generations can be observed. The bulk of plagioclase crystals is of zonal structure, but zoneless sections can also be encountered. The anorthite content of zonal plagioclases varies between 70 and 86%.

The plagioclases are of bladed, tabular habit according to the face (010). Twinned formations are very frequent, twin plates are rather wide. Among the crystal faces types (110) and ($1\bar{1}0$) can frequently be encountered. Besides cleavages (001) and (010) also cleavages according to (110) and ($1\bar{1}0$) are well measurable. Predomimant composition faces are: the most frequent plane is (010) and some irregular composition planes among the multi-composed twin formations are also relatively frequent.

Many crystal groups consisting of a number of twin complexes are present and their ratio as compared with that of "common" twins is high. The complicate complexes consisting of several twin members show sometimes a well observable matrix inclusion structure, which seems to be uniform as if it surrounded a common core.

This rock was the source of the plagioclase twin crystal on the thin section of which one can measure the left form of the "Börzsöny-twin-law", the ($1\bar{1}0$) face as composition and twin plane. The method of vector-geometrical computation for the interpretation of observed data of plagioclase twin crystals was discussed in an article of mine published in common with Mrs Örkényi – Bondor L. (1974).

Observed and computed data of the plagioclase twin crystal figuring in sample Sz. 2. are as follows:

Denotations used in the course of computation:

M_{I_0} = unit vector of the (010) face normal in the first complex,
M_{II_0} = unit vector of the (010) face normal in the second complex,
Z_{I-II_0} = unit vector of the [001] zone axis in the first and second complex,

$$K_0 = \frac{\perp [001]}{(010)} = \text{unit vector of the "roc-tourné" twin axis,}$$

T_0 = unit vector of the ($1\bar{1}0$) face normal,
a_0 = unit vector of the direction of highest optical elasticity,
b_0 = unit vector of the direction of medium optical elasticity,
c_0 = unit vector of the direction of lowest optical elasticity.

The upper case letter figuring as index in the right lower corner of the letter denoting the vector represents the corresponding twin member. The apostrophe in the right upper corner denotes the transformed value of the vector. The marking (with letters) of the morphological directions agrees with the Goldschmidt marking system.

The measured data of the twin crystals shown in Fig. 1. are as follows:

I. = first complex containing the members A, B, C.

Its cleavage and twinning face is:

M_I = n = 113.5°, h = 17.7°.

II. = second complex containing the members D and E.

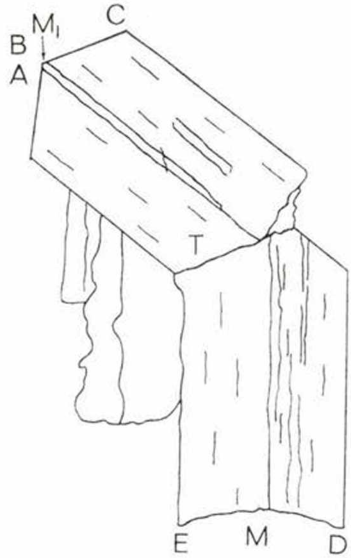

Fig. 1. Plagioclase twin crystal in andesite of Dömörkapu.

Its cleavage and twinning face according to (010) is:

$$M_{II} = \mathrm{n} = 237°,\ \mathrm{h} = 4.5°.$$

The $(1\bar{1}0)$ twinning and composition plane appearing between the two complexes is as follows:

$$T = \mathrm{n} = 177.5°,\ \mathrm{h} = 26°.$$

The $(1\bar{1}0)$ direction appears in either twin members in the form of growth lines, crystal faces and parting too.

The $(1\bar{1}0)$ direction of the two complexes is alternatively parallel to the (010) direction of the other complex.

$$M_{I_0} = -0.87340\, i - 0.37976\, j + 0.30486\, k$$

$$M_{II_0} = +0.83608\, i - 0.54295\, j + 0.37460\, k$$

$$T_0 = -0.04043\, i - 0.92629\, j + 0.37460\, k.$$

A twin-member:

$$\mathrm{n}_b = 234° \qquad \mathrm{h}_b = 3.5°$$

$$b_{A_0} = +0.80750\, i - 0.58668\, j + 0.06104\, k$$

$$\mathrm{n}_a = 326° \qquad \mathrm{h}_a = 30.5°$$

$$a_{A_0} = +0.48181\, i + 0.71431\, j + 0.50753\, k$$

$$c_{A_0} = [b_{A_0} \times a_{A_0}] = -0.34136\, i - 0.38042\, j + 0.85947\, k.$$

B twin-member:

$$n_b = 236.5^\circ \qquad h_b = 8.5^\circ$$

$$b_{B_0} = +0.82471\,i - 0.54586\,j + 0.14780\,k$$

$$n_c = 328^\circ \qquad h_c = 12^\circ$$

$$c_{B_0} = +0.51833\,i + 0.82950\,j + 0.20791\,k$$

$$a_{B_0} = [b_{B_0} \times c_{B_0}] = -0.23608\,i - 0.09485\,j + 0.96703\,k\,.$$

C twin-member:

$$n_b = 180.5^\circ \qquad h_b = 20^\circ$$

$$b_{C_0} = +0.00819\,i - 0.93965\,j + 0.34202\,k$$

$$n_c = 280^\circ \qquad h_c = 25^\circ$$

$$c_{C_0} = +0.89252\,i + 0.15737\,j + 0.42261\,k$$

$$a_{C_0} = [b_{C_0} \times c_{C_0}] = -0.45093\,i + 0.30180\,j + 0.83994\,k\,.$$

D twin-member:

$$n_b = 175^\circ \qquad n_b = 24.5^\circ$$

$$b_{D_0} = -0.07930\,i - 0.90649\,j + 0.41469\,k$$

$$n_c = 277^\circ \qquad n_c = 24.5^\circ$$

$$c_{D_0} = +0.90317\,i + 0.11089\,j + 0.41469\,k$$

$$a_{D_0} = [b_{D_0} \times c_{D_0}] = -0.42189\,i + 0.40742\,j + 0.80992\,k\,.$$

E twin-member:

$$n_c = 18^\circ \qquad h_c = 18^\circ$$

$$c_{E_0} = -0.29388\,i + 0.90450\,j + 0.30901\,k$$

$$n_b = 115^\circ \qquad h_b = 20.5^\circ$$

$$b_{E_0} = -0.84890\,i - 0.39585\,j + 0.35020\,k$$

$$a_{E_0} = [c_{E_0} \times b_{E_0}] = +0.43908\,i - 0.15940\,j + 0.88416\,k\,.$$

A and B : Z_I of Carlsbad; D and E : Albite M_{II}.
B and C : K_I of Roc-Tourné.
A and C : Albite M_I.

A and E : twin T of Börzsöny.

In every twin-member, the orthogonality of the two optical symmetry-axes must be examined. If the angle subtended by them is really 90°, then the product of their unit vectors is zero. This is, of course, impossible owing to the measurement errors. Up to a deviation of 0.5° the numerical data should not be changed, but in case of an error surpassing 0.5° one has to apply an adjusting procedure. Concerning the data published above no such deviations occurred, so that no use of adjusting was necessary.

Computing of the twin axes is carried out on the basis of bisector vectors of the optical directions. The computation of bisector vector takes place by means of addition, respectively subtraction of unit vectors of the corresponding directions. The obtained vector must be reduced to unit vector form.

The bisectors of optical symmetry-axes of A and B are:

$$\begin{aligned} Z_{Ia_0} &= +0.15186\, i+0.38281\, j+0.91126\, k \\ Z_{Ib_0} &= +0.17650\, i+0.41870\, j+0.88993\, k \\ Z_{Ic_0} &= +0.15107\, i+0.38335\, j+0.91116\, k. \end{aligned}$$

Owing to the closeness of the two $[n_\beta]$-s the mean value of the bisector of the directions $[n_\alpha]$ and $[n_\gamma]$ is computed and used in what follows:

$$Z_{I_0} = +0.15147\, i+0.38308\, j+0\ 91121\, k.$$

The bisectors of optical directions of A and C twin-members are:

$$\begin{aligned} M_{Ia_0} &= -0.86953\, i-0.38456\, j+0.30988\, k \\ M_{Ib_0} &= -0.87086\, i-0.38457\, j+0.30613\, k \\ M_{Ic_0} &= -0.87193\, i-0.38003\, j+0.30871\, k. \end{aligned}$$

The unit vector computed on the basis of the measurements is:

$$M_{I_0} = -0.87340\, i-0.37976\, j+0.30486\, k.$$

For the subsequent computations the measured M_I value will be used, because it is subtending an angle of 90° with the unit vector of Z_I. From these two directions the unit vector of the twin-axis of Roc-Tourné will be computed by means of vectorial multiplication:

$$K_{I_0} = [Z_{I_0} \times M_{I_0}] = +0.46283\, i-0.84203\, j+0.27706\, k.$$

The twin axis of Roc-Tourné results from the optical data of B and C as follows:

$$\begin{aligned} K_{Ia_0} &= +0.45843\, i-0.84635\, j+0.27118\, k \\ K_{Ib_0} &= +0.47000\, i-0.83827\, j+0.27640\, k \\ K_{Ic_0} &= +0.46852\, i-0.84156\, j+0.26882\, k. \end{aligned}$$

Because the value obtained by means of vectorial multiplication is the more accurate one, we will use it instead of the measured values, but we see that the deviation is insignificant.

The bisectors of the optical directions of twin-members D and E are:

$$M_{IIa_0} = +0.83308\, i - 0.54846\, j + 0.07183\, k$$
$$M_{IIb_0} = +0.83124\, i - 0.55154\, j + 0.06965\, k$$
$$M_{IIc_0} = +0.83122\, i - 0.55108\, j + 0.07338\, k.$$

The average value is:

$$M_{II_0} = +0.83185\, i - 0.55036\, j + 0.07162\, k.$$

The unit vector computed from the measured direction is:

$$M_{II_0} = +0.83608\, i - 0.54295\, j + 0.07845\, k.$$

This latter value subtends the angle 89° 30′, with the twin axis of Carlsbad and so it is just to be accepted.

The optical bisectors between twin-members A and E are:

$$T_{a_0} = -0.04487\, i - 0.91739\, j + 0.39546\, k$$
$$T_{b_0} = -0.03884\, i - 0.92176\, j + 0.38580\, k$$
$$T_{c_0} = -0.03395\, i - 0.91867\, j + 0.39356\, k.$$

The unit vector computed from the mean value is:

$$T_0 = -0.03922\, i - 0.91928\, j + 0.39162\, k.$$

The angle subtended by this with the twin-axis of Carslbad is 89° 56', i.e. it is more accurate, than the T_0 vector computed from the measurement.

The bisector of the (010) directions of the two complexes is:

$$T_{M_0} = -0.03732\, i - 0.92284\, j + 0.38336.k.$$

Let us transform the vector T_0 into the coordinate system XYZ (X-axis: twin-axis of Roc-Tourné, Y-axis: Albite twin axis, Z-axis: twin-axis of Carlsbad). We obtain:

$$X = -K_{I_0} = -0.46283\, i + 0.84203\, j - 0.27706\, k,$$
$$Y = +M_{I_0} = -0.87340\, i - 0.37976\, j + 0.30486\, k,$$
$$Z = +Z_{I_0} = +0.15147\, i + 0.38308\, j + 0.91121\, k.$$

The sign of the axes of the coordinate system XYZ has been fixed basing on the Euler angles of first kind.

The transformed value of the T – twin-axis in system I. is:

$$T'_0 = +0.86441\, i' - 0.50275\, j' + 0.00225\, k'.$$

The Goldschmidt values are:

$$\varphi' = 120.5° \qquad \varrho' = 89.9°.$$

Thus, between the twin-members A and E twin-law according to $(\bar{1}10)$ can be observed, i.e. the left form of the "Börzsöny" twin-law.

The observed data are shown in the annexed stereogram (Fig. 2.)

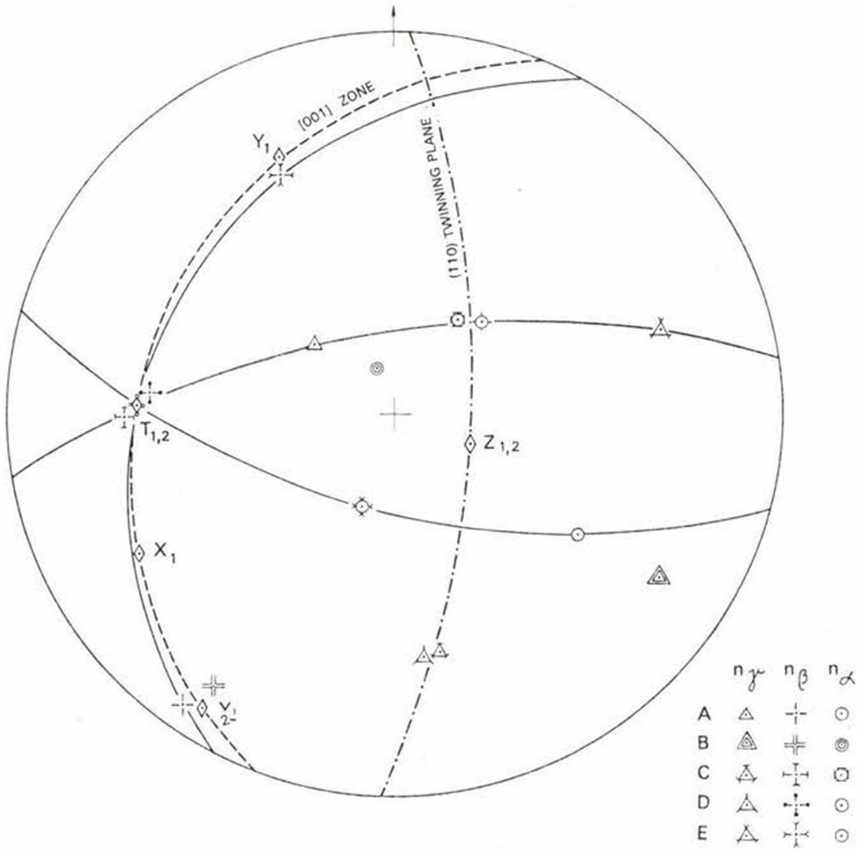

Fig. 2. Stereogram of a plagioclase twin crystal observed in andesite of Dömörkapu.

The interpolated values for the case of an anorthite content of 85% are for $(1\bar{1}0)$ as follows:

$\varphi = 119.5°$, $\qquad \varrho = 90°$.

The anorthite content of the twin crystal corresponds on the migration curve to 83 – 84%, the observation points are lying along the HT curve within a distance of 1 mm.

REFERENCES

B a r t h, T. W., 1969: Feldspars, London (1 – 261)

B u r r i, C. 1950: Anwendung der Vektorrechnung auf einige häufig auftretende kristal-optische Probleme. S. M. P. M. 30. (258 – 300).

B u r r i, C., 1956: Charakterisierung der Plagioklasoptik durch drei Winkel... S. M. P. M. 36. (539 – 592).

B u r r i, C., 1968: Die optische Orientierung von HT-labradorit aus Andesit von Kuchiré (Iran). S. M. P. M. 48. (781–801).

B u r r i, C., 1972: Zur Definition und Berechnung der optischen Orientierung von Plagioklasen. S.M. P. M. 52. (497–514).

B u r r i, C., 1974: Chemismus und optische Orientierung zweier Bytownits aus islandischem Olivinbasalt. S. M. P. M. 54. (1–17).

B u r r i, C., P a r k e r, R., W e n k, E d., 1967: Die optische Orientierung der Plagioklase. Basel. (1–334).

B u r r i, C., Ö r k é n y i - B o n d o r, L., V i n c z e - S z e b e r é n y i, H., 1976: Rechnerische Auswertung von U-Tischoperationen durch elementare Vektormethoden. S. M. P. M. 56. (1–38).

H a j ó s, Gy., 1966: Introduction to the geometry. Budapest (in Hungarian 1–594).

K o c h, S., S z t r ó k a y, K. I., 1967: Mineralogie (Budapest, in Hungarian, 1–936).

K ö h l e r, A., 1950: Bemerkungen über Plagioklaszwillinge. Min. Petr. Mitt. Tscherm. 3. Serie 1. (347–352).

K ö h l e r, A, R a a z, F., 1945–47: Gedanken über die Bildung von Feldspatzwillingen in Gesteinen. Verh. Geol. Bund. Wien (163–171)

L e n g y e l, E., 1925: Petrogenetische Beobachtungen an den Andesiten von der Umgebung von Pilisszentlászló . Földt. Közl. 55 (1q8–127, in Hungarian).

Ö r k é n y i – B o n d o r, L., V i n c z e – S z e b e r é n y i, H., 1974: (110), ($1\bar{1}0$), (130) and ($1\bar{3}0$) Plagioclase Twinning in Andesite from Hungary, Acta Geol. Ac. Sc. Hung. 18., (99–135).

R e i n h a r d, M., 1931: Universale Drehtischmethoden. Basel.

W e n k, E d, G l a u s e r, A. Schwander, H., T r o m m s d o r f, V., 1972: Twin laws, optic orientation and composition of plagioclases from rocks 12 051, 14 053 and 14 310. Geoch. Cosmoch. Acta 1. (581–589).